

Appendix C – Flaw Distribution, Correspondence with Dr. Fredric Simonen of the Pacific Northwest National Laboratory

The following report details the flaw distribution adopted in FAVOR and used in this investigation.

Simonen 10-03

F.A. Simonen, S.R. Doctor, G.J. Schuster, and P.G. Heasler, “A Generalized Procedure for Generating Flaw Related Inputs for the FAVOR Code,” NUREG/CR-6817 Rev. 1, October 2003.

This appendix includes the text of a letter sent to the primary author of this report, Dr. Fredric Simonen, and Dr. Simonen’s response. The purpose of the letter was to clarify Dr. Simonen’s views regarding the extent to which the flaw distributions reported in NUREG/CR-6817, Rev. 1 apply to operating PWRs *in general*.

Text of Letter Sent to Dr. Simonen

30th June 2004

MEMORANDUM

From: Mark EricksonKirk (mtk@nrc.gov)
To: Fred Simonen (fredric.simonen@pnl.gov)
cc: Debbie Jackson
Allen Hiser

Subj: NUREG/CR-6817, Rev. 1, “A Generalized Procedure for Generating Flaw-Related Inputs for the FAVOR Code,” by F. A. Simonen, et al.

Motivated by comments received from both the external peer review panel we convened for the PTS project and from some members of the industry I have recently re-read the subject NUREG/CR report. For the PTS reevaluation effort it is important to know to what extent the flaw distributions reported in NUREG/CR-6817, Rev. 1 apply to operating PWRs *in general*. Neither the executive summary nor the conclusions of this report (which I have attached for your reference) speak to this issue. However, I did find the following statements in the body of the report that speak to the question of the general applicability of the flaw distribution:

On p. 5.9 (*emphasis* added):

The PRODIGAL model provided a systematic approach to relate flaw occurrence rates and size distributions to the parameters of welding processes that can vary from vessel-to-vessel. Application of the model showed the sensitivity of calculated flaw distributions to changes in the welding process conditions. *Calculations with PRODIGAL and consideration of known differences in fabrication*

procedures used to manufacture U.S. vessels indicated that data from PVRUF and Shoreham can reasonably be applied to all vessels at U.S. plants.

On p. 6-2 (*emphasis added*)

Use of Data Versus Models and Expert Elicitation - In developing flaw distributions, measured data were used to the maximum extent possible. The PRODIGAL flaw simulation model and results of the expert judgment elicitation were used only when the data were inadequate. In the case of seam welds, there was a relatively large amount of data, and the PRODIGAL model and expert elicitation were not used to quantify estimates of flaw densities and sizes. The PRODIGAL model did, however, suggest the normalization of flaw dimension by the dimensions of weld beads and the separation of data into subsets corresponding to small and large flaws (as defined by flaw depth dimensions relative to the weld bead dimensions). ***In addition, the expert elicitation and the PRODIGAL model helped to justify the application of data from the PVRUF and Shoreham vessels to the larger population of vessels at U.S. nuclear plants.***

The NUREG/CR also includes the following statement:

On p. 6-3 (*emphasis added*)

Vessel-to-Vessel Variability - The PNNL examinations of vessel material focused on two vessels (PVRUF and Shoreham), with only limited examinations of material from other vessels (Hope Creek, River Bend, and Midland). The Shoreham flaws showed some clear differences from the PVRUF flaws with somewhat greater flaw densities and longer flaws (larger aspect ratios). However, there was no basis for relating these differences in flaw densities and sizes to other vessels. With only two examined vessels it was not possible to statistically characterize vessel-to-vessel differences such that the differences could be simulated as a random factor in Monte Carlo calculations. The decision was to develop separate procedures to generate flaw distributions for the PVRUF and Shoreham vessels. ***Following the conservative approach taken in other aspects of the PTS evaluations where data and/or knowledge is lacking, it was recommended that the Shoreham version of the flaw distribution be used in PTS calculations, which served to ensure conservatism in the predictions of vessel failure probabilities.***

The statements from p. 5-9 and 6-2 suggest that the view that the flaw distributions proposed in NUREG/CR-6817, Rev. 1 apply to operating PWRs *in general*. Conversely, the statement made on p. 6-3 seems to suggest that you and your co-authors view the flaw distributions as being *conservative*.

To help me respond to questions I have received regarding use of the flaw distributions presented in the NUREG/CR in the PTS reevaluation project it would be most helpful to me if you could respond to the following question:

What is the view of you and your co-authors? Do you view the flaw distributions published in NUREG/CR-6817, Rev. 1 as being applicable to PWRs in general, or do you view them as being a conservative representation of the flaw population in the fleet of operating PWRs.

I greatly appreciate your assistance with this matter.

Reply Received from Dr. Simonen

>>> "Simonen, Fredric A" <fredric.simonen@pnl.gov> 07/01/04 02:23PM >>>

Mark:

This is my response to the questions that you posed to me in the attached memo (June 30, 2004):

What is the view of you and your co-authors? Do you view the flaw distributions published in NUREG/CR-6817, Rev. 1 as being applicable to PWRs in general, or do you view them as being a conservative representation of the flaw population in the fleet of operating PWRs?

Your June 30, 2004 memo accurately reflects my views and those of my co-authors regarding the applicability of the flaw distributions in NUREG/CR-6817, Rev1 to PWRs in general as well as the conservative nature of the distributions.

In developing the flaw distribution methodology we were guided by Lee Abramson (statistician from NRC staff) in dealing with uncertainties. Because the PNNL flaw data were primarily from two vessels (PVRUF and Shoreham) a rigorous statistical treatment of vessel-to-vessel differences was not possible. The flaw model was therefore developed with separate treatments for the two vessels, along with a recommendation to use the more conservative treatment based on the Shoreham vessel when addressing other vessels. Other conservatisms can be introduced as appropriate in application of the flaw model to address uncertainties in knowledge regarding of a specific vessel. One example of such uncertainties would be the amount of repair welding in a particular vessel.

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Appendix D –Comparison of Plant-Specific Reference Temperature Values

PWR Plant Name	RT _{PTS} at EOL from RVID [°F]	RT at 32 EFY (EOL) [°F]			RT at 48 EFY (EOLE) [°F]			TWCF Estimated Using Eq. 11-2	
		RT _{MAX-AW}	RT _{MAX-PL}	RT _{MAX-CW}	RT _{MAX-AW}	RT _{MAX-PL}	RT _{MAX-CW}	32 EFY	48 EFY
ARKANSAS NUCLEAR 1	237	118	93	173	127	102	184	7.7E-12	1.3E-11
ARKANSAS NUCLEAR 2	123	105	105	105	117	117	117	3.6E-12	7.3E-12
BEAVER VALLEY 1	268	187	228	219	198	243	236	7.2E-10	1.5E-09
BEAVER VALLEY 2	153	85	104	104	88	116	116	1.3E-12	1.8E-12
BRAIDWOOD 1	85	0	33	82	0	36	88	1.3E-14	1.4E-14
BRAIDWOOD 2	70	0	49	78	0	51	83	2.1E-14	2.3E-14
BYRON 1	110	0	78	78	0	84	90	8.1E-14	1.1E-13
BYRON 2	103	0	38	105	0	42	121	1.6E-14	2.2E-14
CALLAWAY 1	115	81	88	88	85	93	93	9.0E-13	1.2E-12
CALVERT CLIFFS 1	253	193	156	156	204	171	171	6.8E-10	1.3E-09
CALVERT CLIFFS 2	198	167	167	167	179	179	179	1.5E-10	3.0E-10
CATAWBA 1	58	0	44	18	0	48	22	1.8E-14	2.0E-14
CATAWBA 2	128	93	93	93	99	99	99	1.7E-12	2.6E-12
COMANCHE PEAK 1	100	67	67	67	75	75	75	3.7E-13	6.0E-13
COMANCHE PEAK 2	92	39	39	39	43	43	43	6.9E-14	8.8E-14
COOK 1	215	153	162	202	166	173	217	6.7E-11	1.4E-10
COOK 2	216	164	181	177	174	193	191	1.3E-10	2.6E-10
CRYSTAL RIVER 3	216	136	131	179	145	139	191	2.3E-11	4.0E-11
DAVIS-BESSE	191	0	80	186	0	85	196	3.0E-13	4.9E-13
DIABLO CANYON 1	258	186	133	129	199	144	141	4.5E-10	1.0E-09
DIABLO CANYON 2	211	184	196	193	195	207	205	4.3E-10	8.2E-10
FARLEY 1	183	142	180	176	154	197	195	4.9E-11	1.1E-10
FARLEY 2	205	166	210	204	181	230	227	2.3E-10	6.1E-10
FORT CALHOUN	268	199	131	165	213	145	178	9.9E-10	2.2E-09
GINNA	226	0	150	201	0	162	211	4.2E-12	8.0E-12
HADDAM NECK	165	147	153	140	166	173	154	4.6E-11	1.4E-10
INDIAN POINT 2	230	200	212	207	214	226	223	1.1E-09	2.6E-09
INDIAN POINT 3	265	244	244	244	257	257	257	1.6E-08	3.4E-08
KEWAUNEE	277	0	123	239	0	134	255	5.0E-12	1.2E-11
MAINE YANKEE	238	186	191	226	198	203	241	4.7E-10	9.7E-10
MCGUIRE 1	219	128	130	130	136	139	138	1.5E-11	2.4E-11
MCGUIRE 2	141	0	100	-27	0	107	-21	2.5E-13	3.6E-13
MILLSTONE 2	177	133	137	137	142	146	147	2.0E-11	3.4E-11
MILLSTONE 3	134	119	119	119	129	129	129	8.2E-12	1.5E-11
NORTH ANNA 1	184	0	160	110	0	169	122	6.4E-12	1.0E-11
NORTH ANNA 2	220	0	176	140	0	188	152	1.5E-11	2.9E-11
OCONEE 1	214	158	84	181	171	91	193	8.1E-11	1.8E-10
OCONEE 2	273	0	75	187	0	80	199	2.9E-13	5.2E-13

PWR Plant Name	RT _{PTS} at EOL from RVID [°F]	RT at 32 EFY (EOL) [°F]			RT at 48 EFY (EOLE) [°F]			TWCF Estimated Using Eq. 11-2	
		RT _{MAX-AW}	RT _{MAX-PL}	RT _{MAX-CW}	RT _{MAX-AW}	RT _{MAX-PL}	RT _{MAX-CW}	32 EFY	48 EFY
OCONEE 3	236	0	85	180	0	91	192	2.6E-13	4.6E-13
PALISADES	269	212	190	202	229	206	216	2.2E-09	6.0E-09
PALO VERDE 1	123	83	83	83	90	90	90	9.8E-13	1.5E-12
PALO VERDE 2	78	53	53	53	60	60	60	1.6E-13	2.5E-13
PALO VERDE 3	68	43	43	43	50	50	50	9.0E-14	1.4E-13
POINT BEACH 1	274	171	116	226	181	123	240	1.8E-10	3.4E-10
POINT BEACH 2	288	0	114	217	0	123	230	1.8E-12	3.4E-12
PRAIRIE ISLAND 1	163	0	97	123	0	112	138	2.2E-13	4.9E-13
PRAIRIE ISLAND 2	150	0	93	107	0	108	122	1.8E-13	3.8E-13
ROBINSON 2	255	146	152	196	154	160	209	4.4E-11	7.1E-11
SALEM 1	253	218	225	222	231	238	235	3.4E-09	7.0E-09
SALEM 2	227	166	152	151	180	163	161	1.4E-10	3.1E-10
SEABROOK	120	91	91	91	100	100	100	1.6E-12	2.7E-12
SEQUOYAH 1	235	0	203	150	0	218	164	6.6E-11	1.4E-10
SEQUOYAH 2	152	0	113	81	0	123	90	4.8E-13	8.3E-13
SHEARON HARRIS	196	147	163	162	153	172	170	5.0E-11	7.2E-11
SONGS-2	146	147	147	147	162	162	162	4.5E-11	1.1E-10
SONGS-3	125	110	110	110	122	122	122	4.8E-12	1.0E-11
SOUTH TEXAS 1	84	51	57	57	57	65	65	1.5E-13	2.2E-13
SOUTH TEXAS 2	67	26	31	31	31	37	37	3.3E-14	4.6E-14
ST. LUCIE 1	206	165	150	149	175	159	158	1.3E-10	2.4E-10
ST. LUCIE 2	160	115	115	115	120	120	120	6.5E-12	9.0E-12
SUMMER	113	116	116	116	126	126	126	7.1E-12	1.3E-11
SURRY 1	245	176	145	201	192	161	215	2.5E-10	6.4E-10
SURRY 2	200	152	118	189	164	133	203	5.6E-11	1.2E-10
TMI-1	262	211	73	215	226	80	229	2.0E-09	4.9E-09
TURKEY POINT 3	279	0	102	222	0	108	235	1.9E-12	3.7E-12
TURKEY POINT 4	279	0	96	222	0	103	235	1.8E-12	3.7E-12
VOGTLE 1	118	77	77	-49	82	82	-44	6.6E-13	9.1E-13
VOGTLE 2	126	98	98	98	106	106	106	2.4E-12	3.8E-12
WATERFORD 3	76	69	69	69	77	77	77	4.2E-13	6.6E-13
WATTS BAR 1	253	0	175	97	0	185	106	1.4E-11	2.4E-11
WOLF CREEK	104	81	81	81	87	87	87	8.4E-13	1.2E-12
ZION 1	258	146	102	196	160	115	211	4.1E-11	9.3E-11
ZION 2	272	162	119	225	175	132	241	1.1E-10	2.3E-10

Notes: Plants having a RT_{MAX-AW} value of 0 are forged vessels.
TWCF estimated using Eq. 11-2.
 RT_{MAX-AW} , RT_{MAX-PL} , and RT_{MAX-CW} are defined in Eq. 8-1, 8-2, and 8-3, respectively.
 RT_{PTS} values taken from [RVID2].